



Pressurized Fabric Structures: Applications and Mechanics Research

The Ninth Annual JLOTS



Logistics-from-the-Sea Symposium

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Airbeam Technology



- **Load Bearing Pressurized Fabric Structures**
- **Pressurization pre-tensions the fibers, creating a structure that is rigid under design loads, but deflects without damage when overloaded.**
- **Achieves outstanding strength-to- weight ratios.**



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Shelter Technology



- Replace metal structural frame shelters with inflatable arches or “airbeams” to provide:
 - Rapid, Easy Deployment
 - Reduce Weight
 - Low Cube
- Available in widths ranging from 20 feet to 85 feet for applications such as command/control, medical, vehicle/aircraft maintenance



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Manufacturing Technology



**Braiding
Technology**



**Weaving
Technology**

- **Two new textile technologies produce seamless tubular braided or woven fabrics with high pressure capacity (30-80 psi)**
- **Curvature and bending resistance are obtained by using coated high-tenacity fibers and controlling fiber orientation.**



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Structures

(Established in 2001 at the Natick Soldier Center in
Natick, MA)

Increase durability,
reliability and
affordability

Establish predictive
design tools and models

Market and Document
Technology

Partner with DoD and
government agencies,
industry, and academia

Broaden inflatable structure
applications and commercial
use of the technology

Vision

Deliver new shelter technology into
the hands of soldiers and commercial users.

New Shelter Technology

Future Medical Shelter System

- 4 Airbeams, 14 inches in diameter
- Internal Air Beam Pressure 60 psi
- Clear Floor Area: 1750 sq. ft.
- Deploy in 20 minutes





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Rapid Inflation System for Airbeam



Successfully Tested Prototypes



**Oil-flooded Screw
Compressor**



**Oil-free Scroll
Compressor**



**Oil-free Wobble Piston
Compressor**

Scalable Objective MET

**Increase capacity,
by a factor of five,
over commercially
available, portable
air compressors,
through the use of
innovative
engineering design,
lightweight
materials, and high-
speed components**



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Durability, Reliability, Affordability

- Durable
Puncture and Small Arm
Resistant
- Reliable
Pressure Check Weekly
- Affordable
New Manufacturing
Technology
Achieved Significant Cost
Reduction



Aviation
Inflatable
Maintenance
Shelter
at Holloman AFB
VERTIGO INC



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Broaden Applications



VERTIGO
INC.

Army

**Extended Range Aerial
Delivery System
(ERADS)**

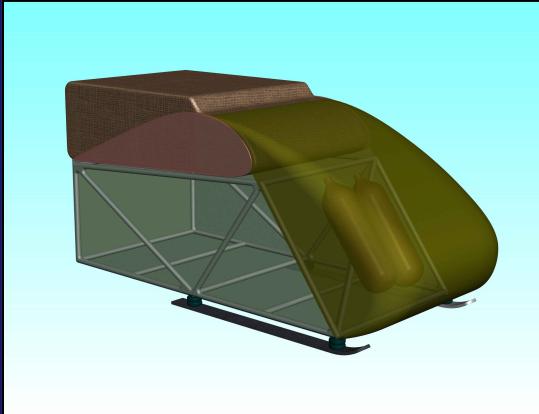
**Remote controlled
glider
that delivers cargo to
troops on the ground**



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Broaden Applications Extended Range Aerial Delivery System



Configuration in aircraft
(Pre-deployment)

Inflatable tubes form the wing





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Broaden Applications



Inflatable Ladder

- Weighs 55 lbs
- Inflation Pressure of 40 psi



VERTIGO INC.
COMPOSITE TECHNOLOGY



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Broaden Applications



NASA

Quickly Deployable Space Structures

- **Inflatable Boom
on a Solar Sail**



- **Inflatable
Telescopes**



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Commercialize the Technology Air Beam Shelter in Production



Chemical Biological
Protection Shelter (CBPS)

64 currently deployed in
Iraq

**Federal Fabrics - Fibers,
Lowell, MA
Designed & Produces Airbeam
Frames**

**Saint - Gobain, Merrimack, NH
Designed & Produces -
Softwall Shelter**



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Air Beam Structural Design

DETERMINE

- Air beams / arches
- Diameter
- Safe operating pressure
- # Warp & weft tows per unit length
- Fiber material(s)
- Coating material
- Acceptable Failure Modes

GIVEN

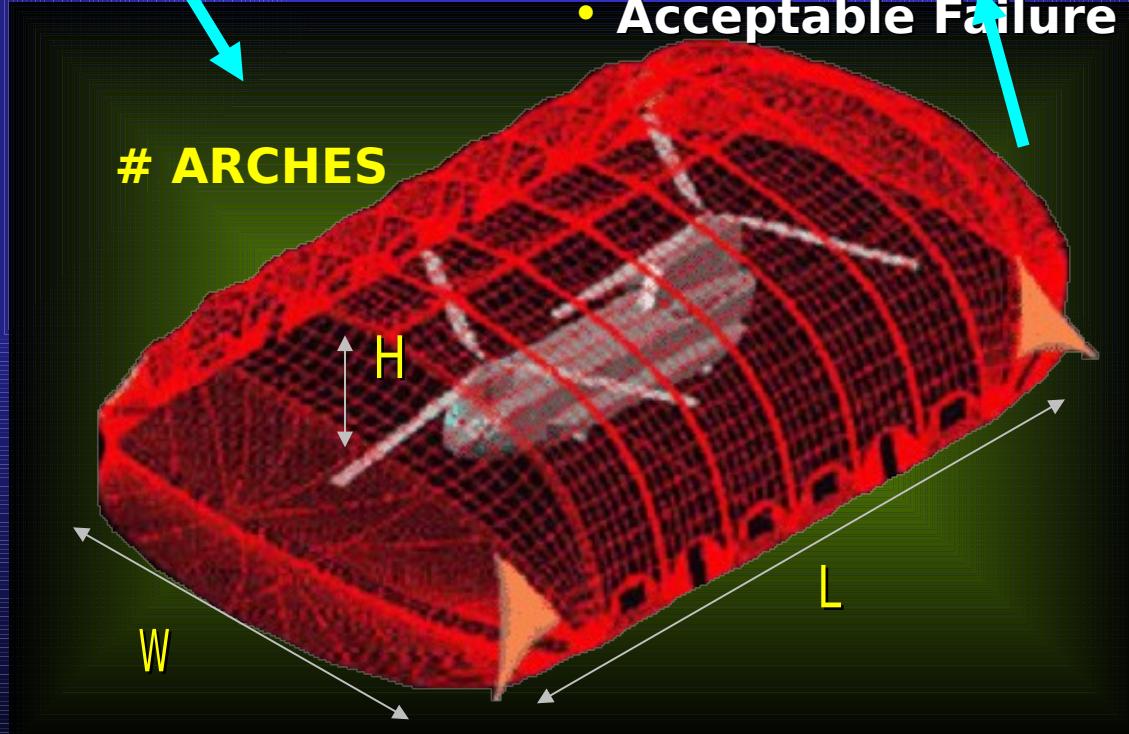
- Floor length & width
- Minimum height requirement
- Environmental Loadings

ARCHES

H

W

L

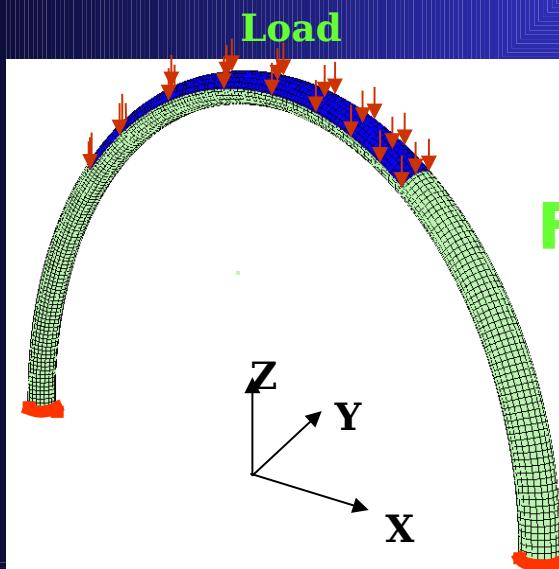


Predictive Tools for Structural Analysis

Dual Approach



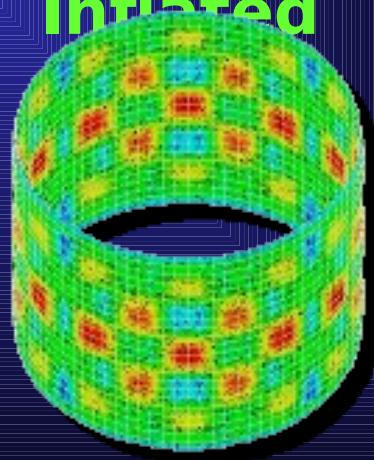
- Predict Structural Response of Air Beam (Wind and Snow Loads)
- Predict Material Behavior



Fabric
Fabric



Inflated





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Structural Analysis





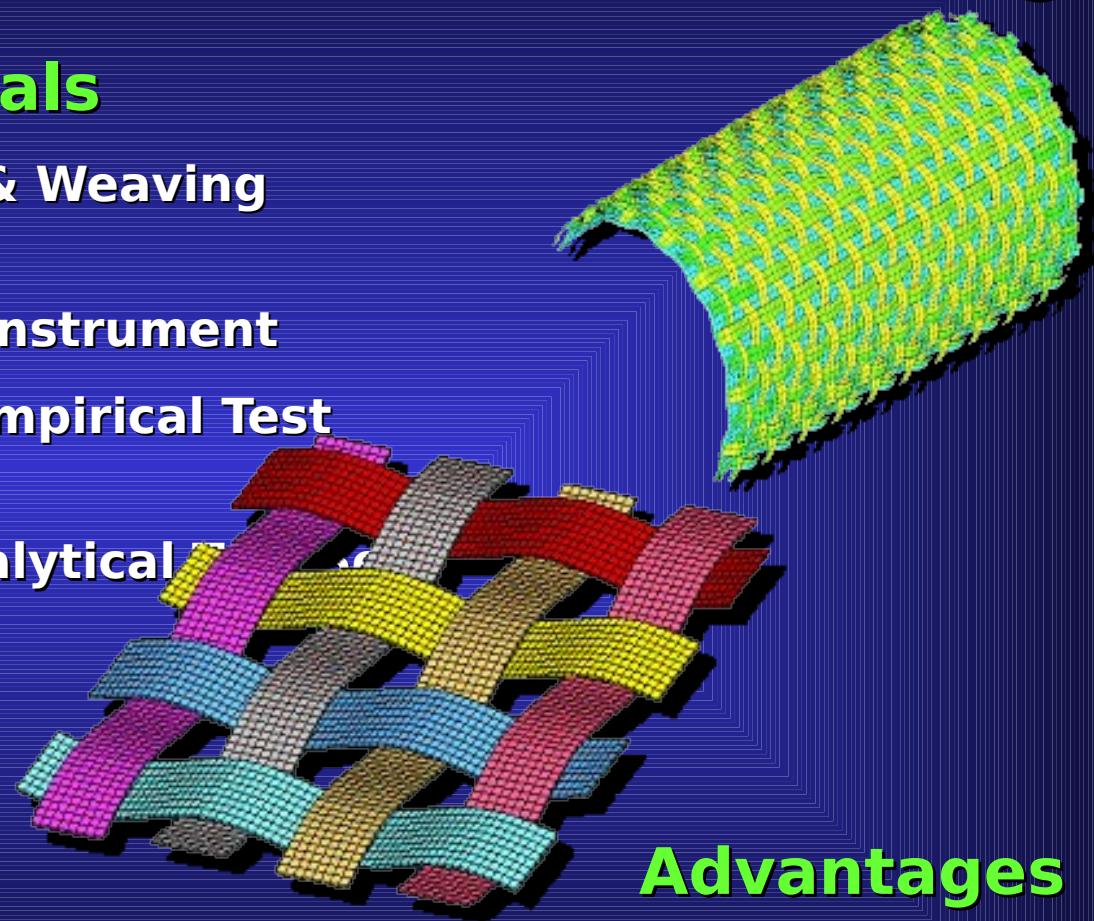
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Modeling Airbeam Structures

Modeling Goals

- Develop 3D Braiding & Weaving Models
- Scalable Verification Instrument
- Collect and Analyze Empirical Test Data
- Create Integrated Analytical Tools

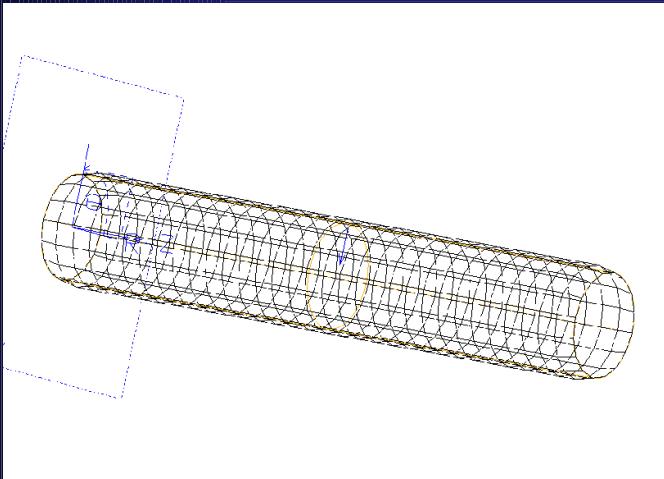


Advantages

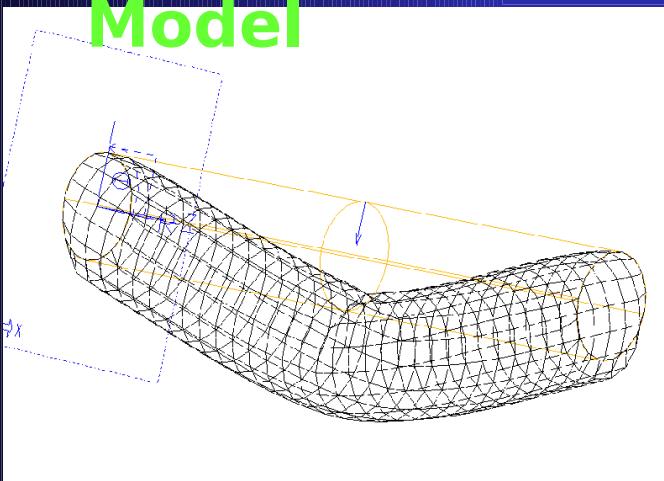
- Analyze Design Problems
- Technology Investment



Element Assumptions and Formulation



**Nastran
Model**



A specialized structural air beam element for inflatable structures

- **Nonlinear fabric mechanics**
- **Modeling work done by inflation pressure**
- **Need to predict folding and wrinkling of fabric**
- **Ease of use when modeling a fabric shelter**



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4-Pt. Flexure Tests on Woven Vectran Air Beams Construction Details



**4-Point Bend Fixture Mounted
in Instron® with Displacement
Wire Transducer Used To
Capture Mid-Span Deflection (5
oz. constant tension force)**

- 3000 denier Vectran
- 13 warps/inch
- 13 wefts/inch
- Strength_{Vectran} = 28 gpd
- Bladder: Estane 58315 TPU
- Bladder_{thick} = 0.008"
- Uncoated
- End Cap: Stitched-on
- Mfg. by Federal
Fabrics/Fibers, Lowell MA
- Diameter = 6 in; Length

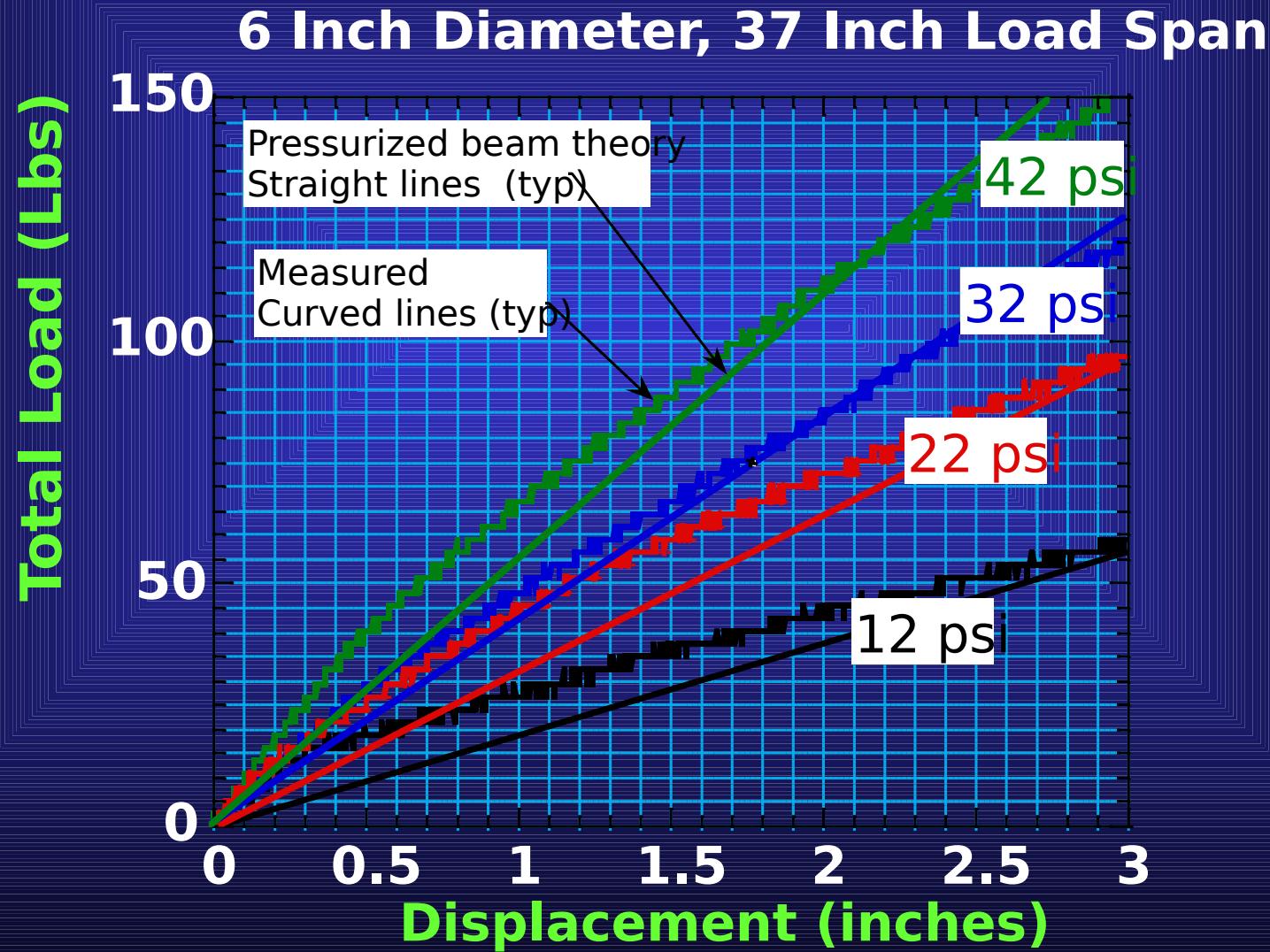




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Comparison of Finite Element and Experimental Results





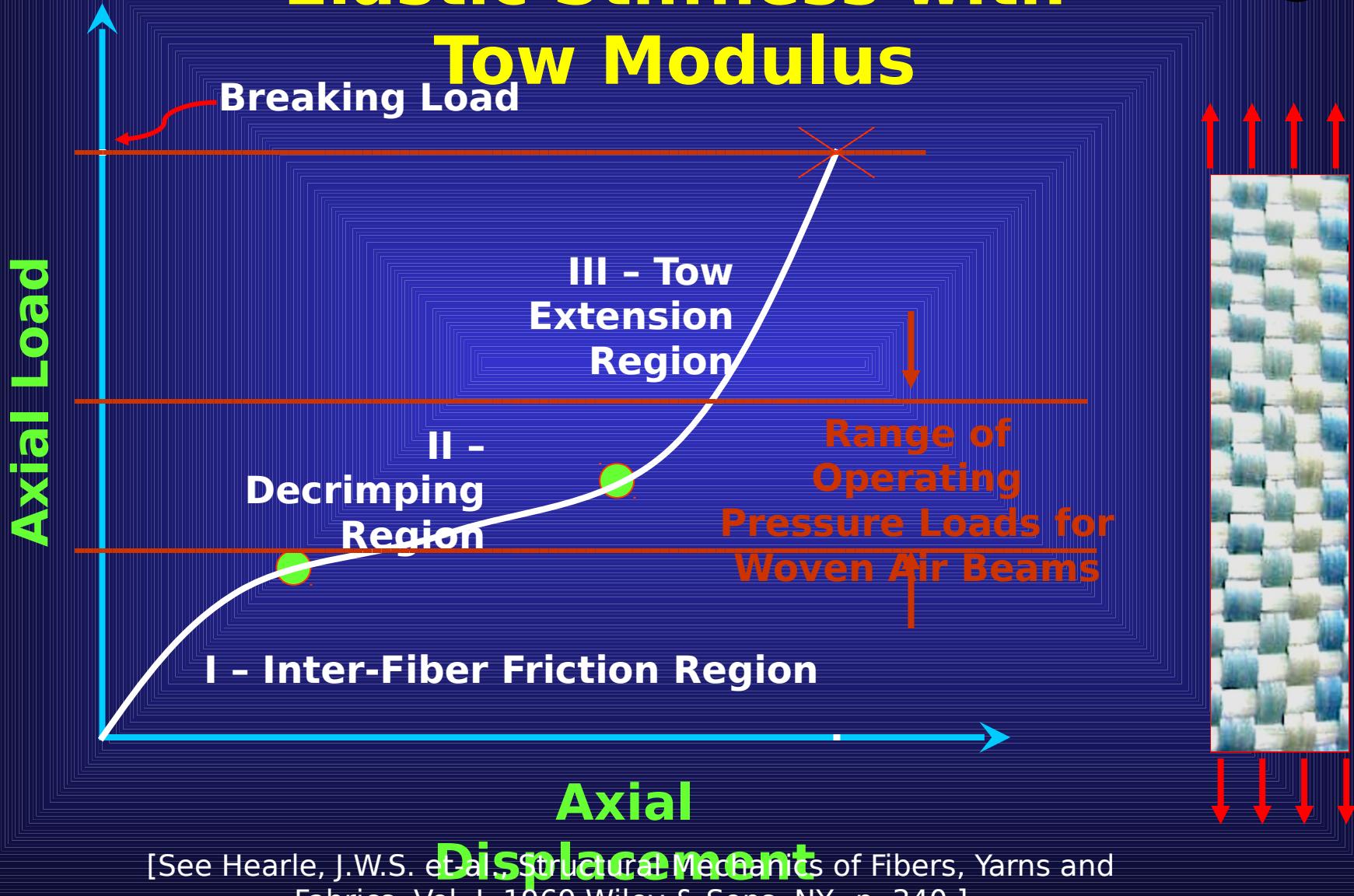
Fabric Mechanics Modeling



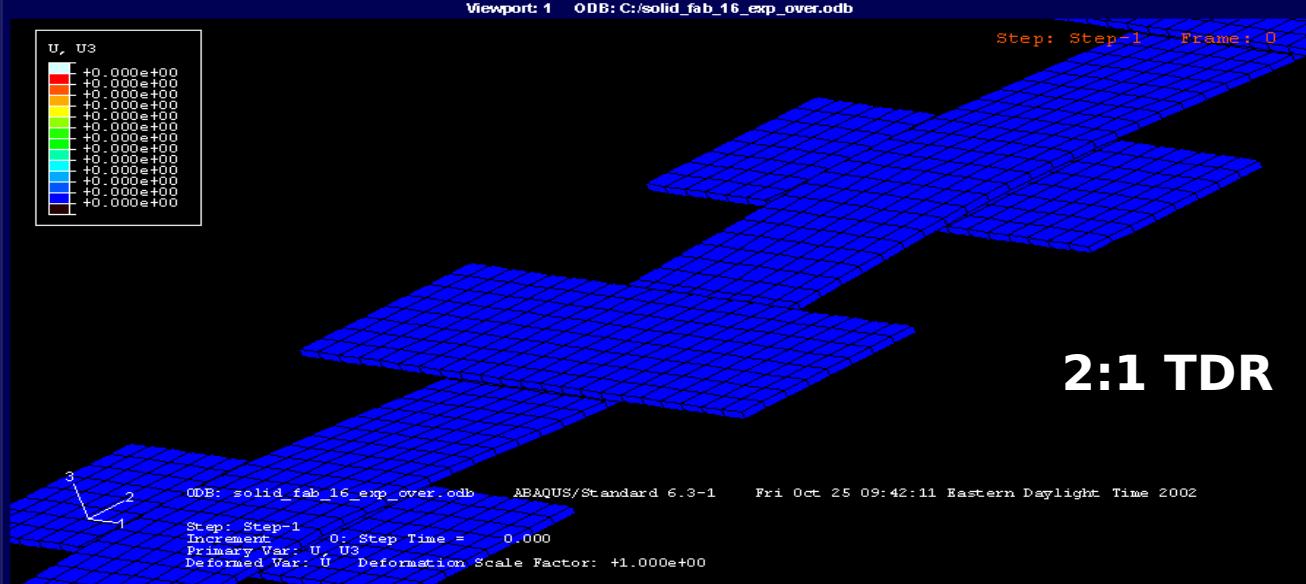
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Invariance of Fabric Elastic Stiffness with Tow Modulus



Fabric Strip Model Description



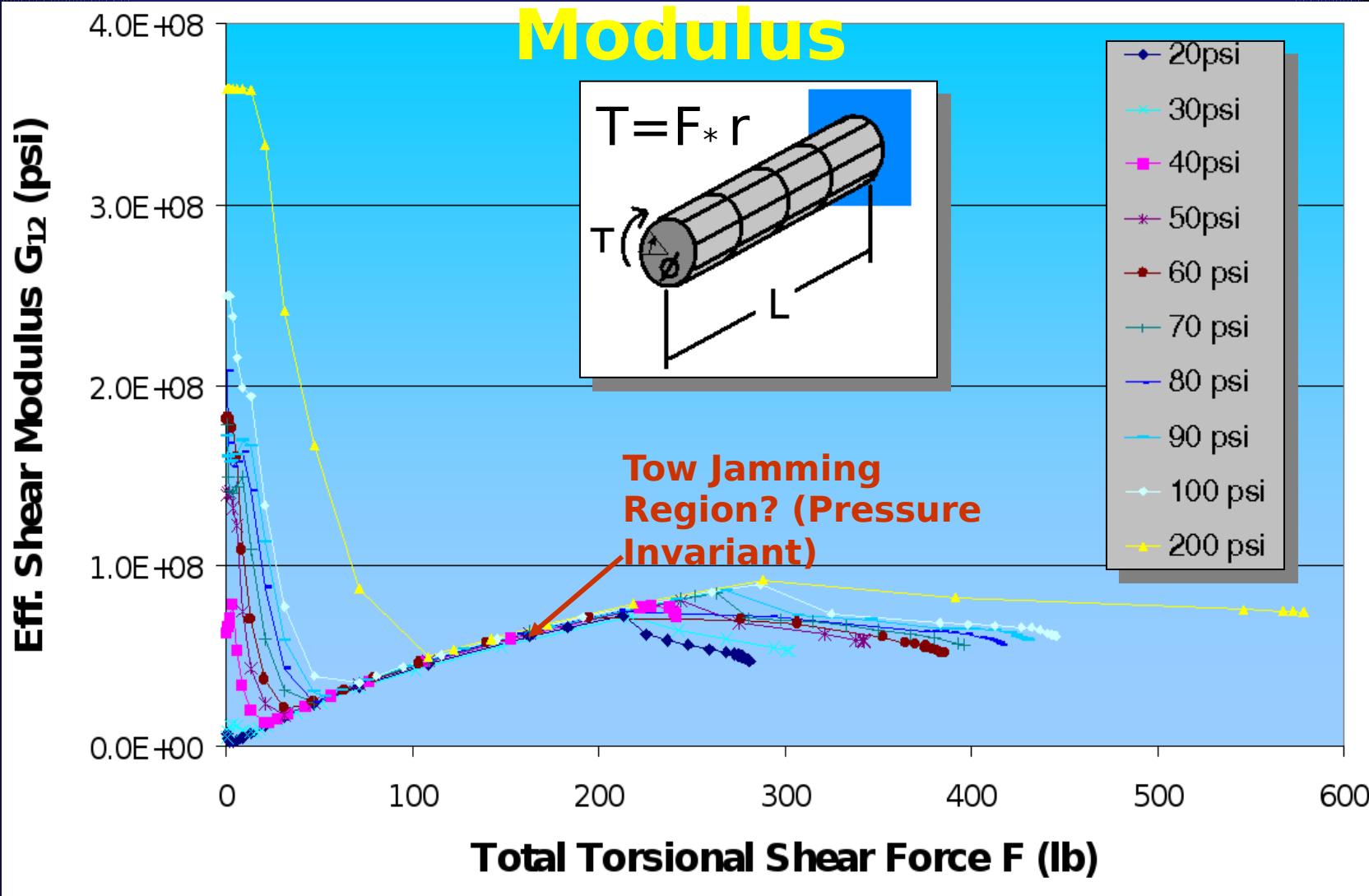
- **ABAQUS® Finite Element Analysis Software**
- **Full surface-to-surface contact of all tows**
- **Typical run times: 3-4 hrs.**



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Pressure & Load Dependent Shear



(2:1 TDR, 1:1 Equi-Biaxial Loading Ratio With Hoop Tow Spacing = 0.0472")

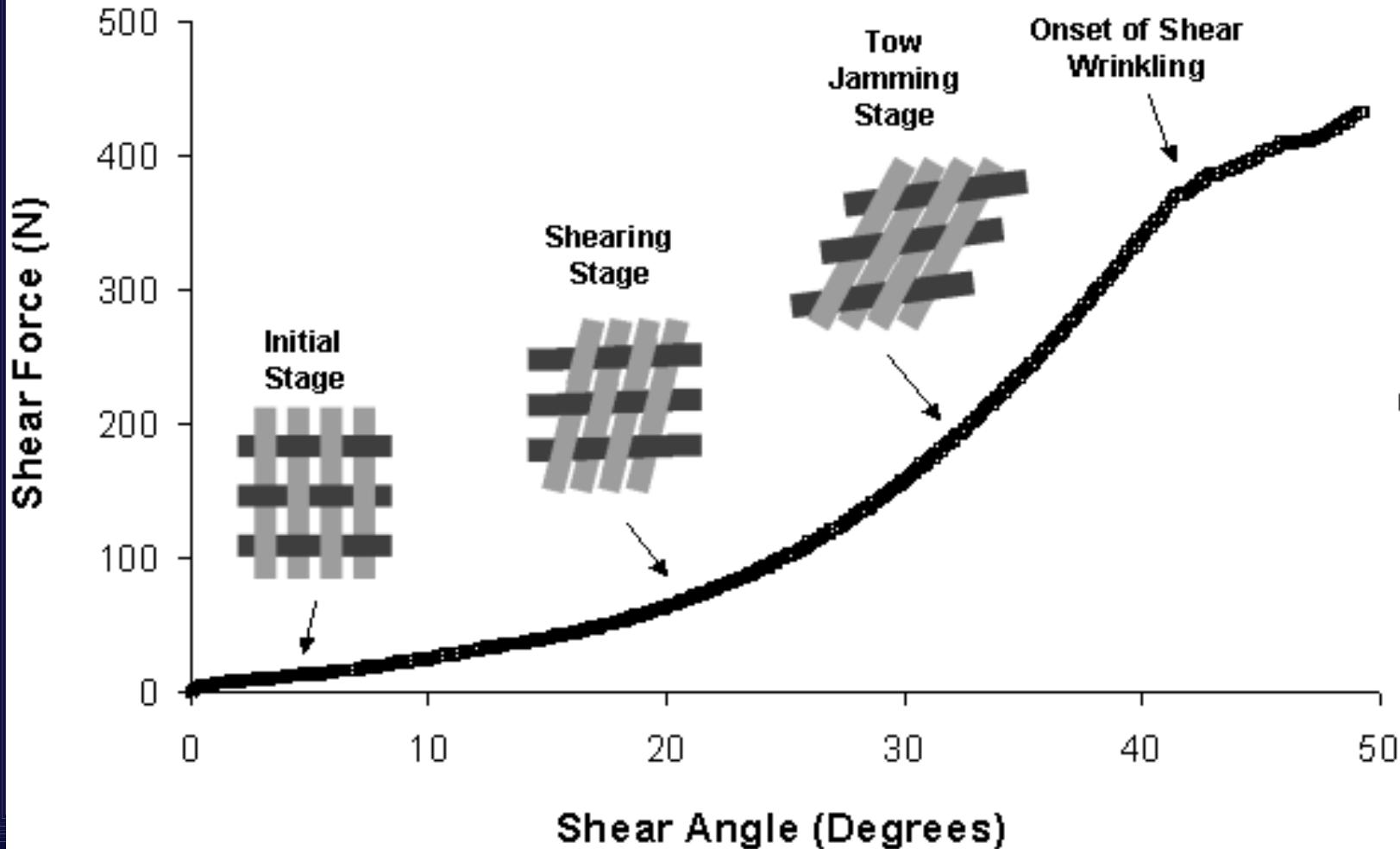


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Stages of Pure Shearing Deformations

2:1 TDR Plain Woven Fabric Subject to Pure Shear

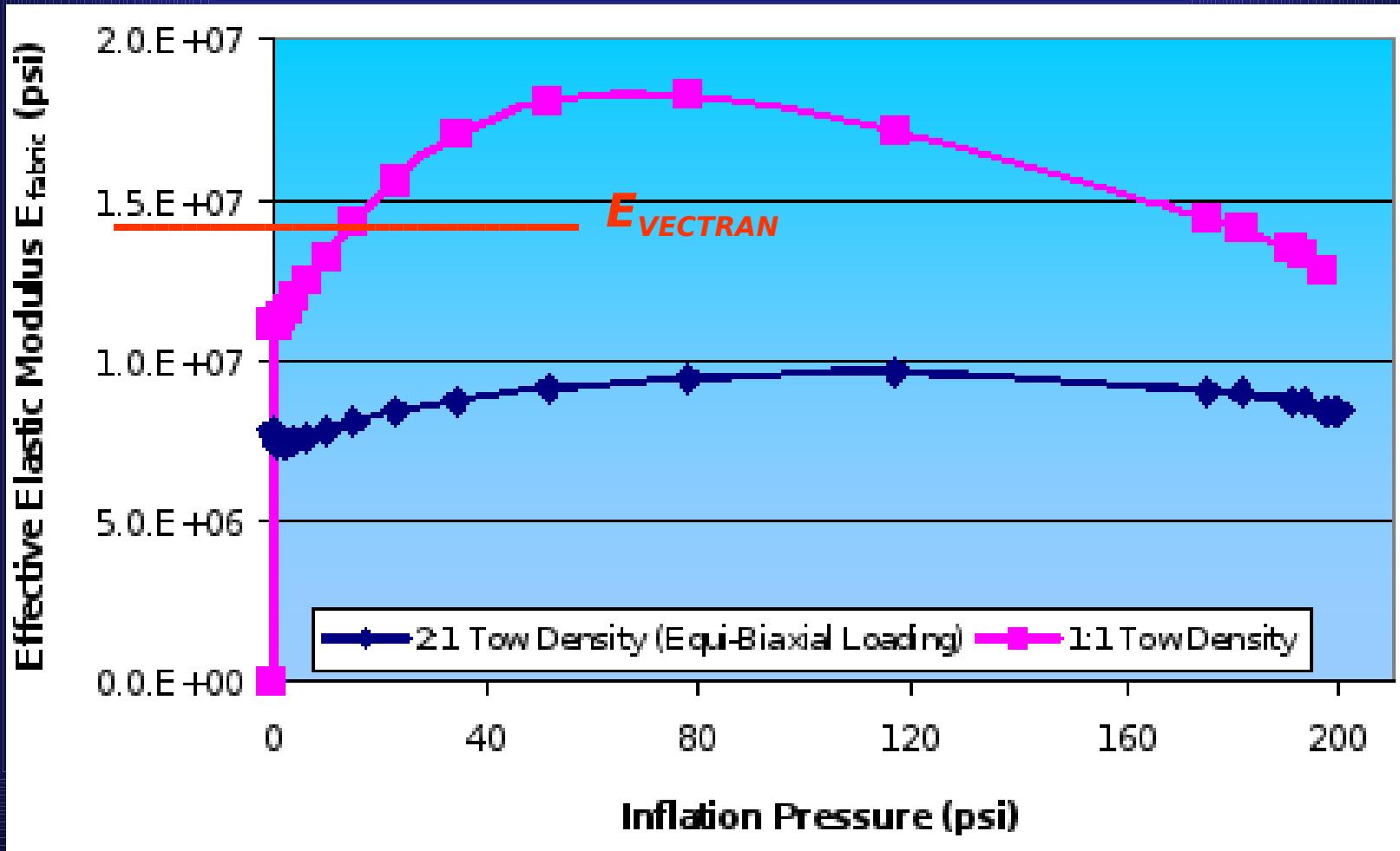




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Fabric Elastic Modulus As Functions of Pressure & TDR



Summary

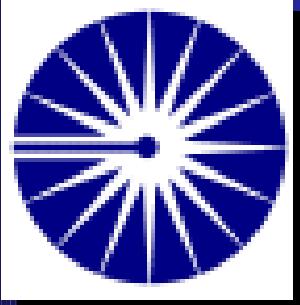
- **Inflated structures are:**
 - proven to be durable and reliable
 - more affordable
 - (Cost reduction is an ongoing process.)
 - sustaining our troops in Iraq
- **Modeling efforts predict structural behavior and inflated fabric properties.**
- **Experimental validation efforts are underway.**



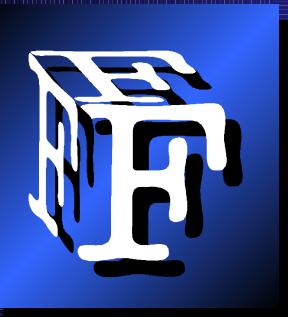
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Yankee Scientific, Inc.



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Federal Fabrics-Fibers, Inc.



City College CUNY, NY



